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Ines Ben Jemaa, Oyunchimeg Shagdar, Paul Mühlethaler, Arnaud de La Fortelle

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Ines Ben Jemaa[1,2], Oyunchimeg Shagdar[4,2], Paul Muhlethaler[2] and Arnaud de La Fortelle[2,3]
1. UVSQ-Prism Lab., France, 45 Avenue des Etats Unis
2. Inria, RITS team, Domaine de Voluceau, 78150 Rocquencourt, France
3. MINES ParisTech, Centre for robotics, 60 Bd St Michel 75006 Paris, France
4. Institut VeDeCoM, 77, Rue des Chantiers, 78000, Versailles, France
Email :{ines.ben_jemaa, oyunchimeg.shagdar, paul.muhlethaler, arnaud.de_la_fortelle}@inria.fr

Abstract
Emerging ITS applications, such as point of interest distribution, require information delivery from the Internet to a group of vehicles. Such an Internet-to-VANET multicast service raises several challenges including efficient multicast mobility management and multicast message delivery in a geographic area (geocast). In this paper we propose to extend the PMIP (Proxy Mobile IP) mobility management scheme such that it allows vehicles in a geographic area to subscribe to the multicast group with low control overhead by exploiting vehicular ad hoc networking. We then propose Melody, a geocast routing protocol, which extends the multicast service coverage in the VANET based on overlay routing. Our simulation results show that Melody provides an improved communication performance in urban areas in comparison to geographic flooding.

Keywords: **MULTICAST, INTERNET, VANET, MOBILITY MANAGEMENT, GEOCAST**

1. Introduction

Intelligent Transport Systems (ITS) are expected to largely improve road safety, efficiency, and driving comfort and therefore it has received a great attention in both the academics and industry. An important goal of ITS is to provide mobile users (e.g., drivers) with the existing Internet-based services (e.g., WEB surfing) as well as new types of services dedicated to the vehicular environments.
A significant number of these ITS applications require multicast communications. Particularly, in addition to the traditional applications such as video conferencing or gaming, vehicular communications enable new emerging multicast applications such as Point Of Interest (POI)

distribution. POI distribution refers to informing drivers and passengers about specific location points (e.g., parking lots, restaurants, and so on), which can be interesting or useful for the nearby road users. This application requires multicast message delivery from a centre in the Internet to a set of users who are located in a specific geographic area. Enabling such an application is fraught with challenges, due to the hybrid communications path (from the Internet to the wireless media and finally to a geographic destination area) and also the highly mobile nature of the destination nodes.

To support multicast services in the Internet, a set of functions are required including multicast addressing [3], membership management [4], and multicast routing [5], [6]. However, the dynamics of vehicular environment and the requirements of geographic dissemination make it difficult to directly extrapolate these protocols to VANETs. In particular, geographic multicasting to VANET mobile users (i.e., drivers and occupants) requires additional challenges including: (i) geographic multicast addressing, (ii) multicast mobility management, and (ii) geographic message dissemination in the wireless network. Regarding geographic multicast addressing, we proposed a solution in [13] that is adapted to the context of vehicular networks. The second and the third challenges are the scope of this current work. The objective of mobility management is to locate mobile users and provide them data in a seamless manner. Two mobility management protocols have been standardized by IETF: (i) the Mobile IPv6 (MIPv6 for IPv6) [7], which is a host-based mobility management, and (ii) the proxy mobile IP version 6 (PMIPv6) [8], which is a network-based mobility management solution. The key idea of MIPv6 relies on a fixed entity in the home network of Mobile Node's (MN), the so-called Home Agent (HA), which locates the MN and builds a bidirectional tunnel to transfer data packets destined to the MN. The weaknesses of MIPv6 include long latency, high signaling overhead and location privacy problems [9]. To overcome these issues, PMIP is designed. In PMIP, the visiting network localizes the MN, communicates with the home entity, and builds a tunnel for data transfer.

Although the existing multicast mobility management solutions can provide multicast data to mobile nodes (MNs), an issue of these solutions is that they are somehow based on the assumption that users usually stay in their home network (fixed network) and hence they are designed to provide mobility management to only one or few users. Therefore, a direct application of these solutions to vehicular services would create large control overhead due to a per-user membership management and inefficient bandwidth utilization due to the unicast transmissions over the tunnels. Such control overhead and inefficient bandwidth usage should be avoided and we believe that it is possible especially for the cases where the mobile members are in the same geographical area. Indeed this is the case for the above-mentioned POI service.

In this paper, we propose to extend PMIPv6 in such a way that mobility management to multiple vehicles can be provided with low cost and low complexity. Specifically, we propose to use PMIPv6 for mobility management to a single user, which further provides mobility management to a multiple users by exploiting vehicular ad hoc networking. Extending PMIPv6 for VANETs has another benefit in contrast to the conventional PMIPv6. Indeed, the mobile users, which do not have Internet connection (because they are not in the coverage of access networks, and/or they are not equipped

with 3G/4G devices), can now receive multicast service over the Internet-to-VANET communication.
A number of efforts towards enabling geocasting in ad-hoc networks have been previously made. Examples are LBM [10] and GeoGrid [11] protocols, which rely on flooding techniques to disseminate a message to a given area. However, if vehicles are in the close proximity of each other, the protocols may lead to a massive packet redundancy on the network, which increases the overhead and bandwidth consumption. Opportunistic routing has been proposed to improve packet delivery and reduce the overhead in the network. Opportunistic routing such as [12] exploits the broadcast nature of wireless transmissions. It allows candidate nodes that overhear the packet and are close to the destination to participate in forwarding the packet and thus reduce the number of retransmissions. However, in multicast services, where the message has to be delivered to the members, opportunistic routing using broadcasting techniques may not guarantee the packet delivery due to the lack of an acknowledgement system.
In this paper, we introduce Melody, a geocast routing protocol that uses a variant of opportunistic routing technique to transmit multicast packets over an overlay path to a geographic area.
The rest of this paper is organized as follows: Section 2 details our proposal for Internet-to-VANET multicasting. More specifically, we explain the scenario and present the VANET multicast group management scheme. In Section 3, we present the dissemination process to deliver information from the Internet to the group of multicast members located in an urban destination area. In Section 4 we assess our proposal by computer simulations for different urban scenarios. Finally, Section 5 concludes the paper.

2. Internet-to-VANET Multicasting

In this section, we first present the scenarios of Internet-to-VANET multicast communication required by the POI application. We then introduce the enhanced mobility management scheme for PMIPv6 architecture.

2.1. Preliminaries and scenario description

The scope of this work is multicast message delivery from a server residing in the Internet to an urban area. The message may include information about road status (congested or not), an advertisement of a new restaurant or parking facilities in a specific area. The messages are first sent to Road Side Units (RSU), which are deployed on a city scale to serve small urban zones. The source (server) sends the message to a multicast address that identifies the multicast service. It also specifies the destination area in the packet. It should be noted here that the destination area is transparent to the entities, which forward the multicast message in the Internet. The role of those entities is to forward the message to the multicast address following the Internet path, e.g., a tree path built by the PIM protocol [6].

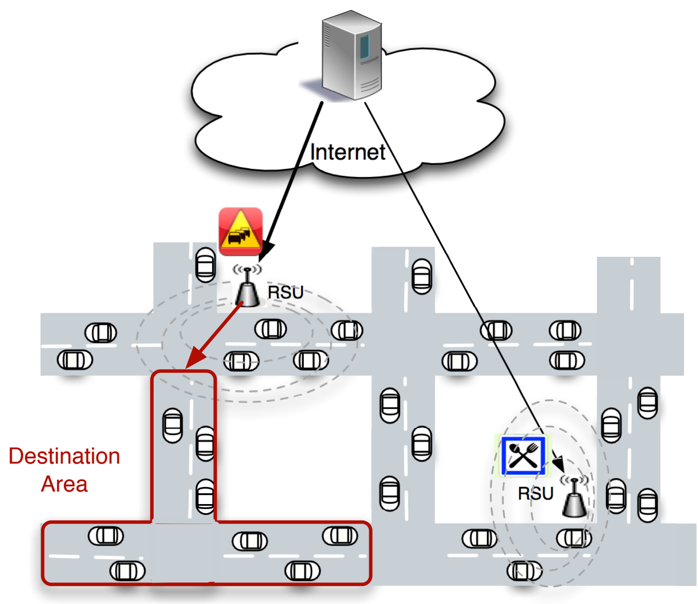

Figure 1 - Internet to VANET Geocast scenario

The scenario is depicted in **Figure 1**. When an RSU receives the information sent from the server, it has to forward it to the interested vehicles, which reside in a geographic area specified in the data packet. The multicast vehicles use the mechanism as detailed in [13] to auto-configure a valid address using the service identifier and the geographic attributes of the area. If the destination area is not directly reachable from the RSU, the data has to be relayed in the vehicular network from the RSU until the geographic area, where it is disseminated to the multicast members.

2.2. Extended multicast mobility management for the PMIPv6 architecture

The membership management and data transmission in PMIPv6 multicast mobility management schemes are illustrated in **Figure 2**. The Mobile Access Gateways (MAGs) broadcast a Multicast Listener Query MLQ (MLQ) to Mobile Nodes (MN) under their coverage, collect Multicast Listener Report (MLR) from them, and send aggregated MLRs to their respective Local Mobility Anchor (LMA).

As illustrated in **Figure 2**, the control overhead and bandwidth utilization in PMIPv6 degrades with the increase of the number of multicast mobile nodes. Moreover, PMIP cannot obviously deliver data to the MNs that do not have Internet connection.

Targeting the above-mentioned issues, we propose to extend the multicast mobility management by exploiting the VANET concept. In the proposed scheme, the RSU plays the role of the MAG. RSU will be aware about the existence of multicast group in the destination area as follows.

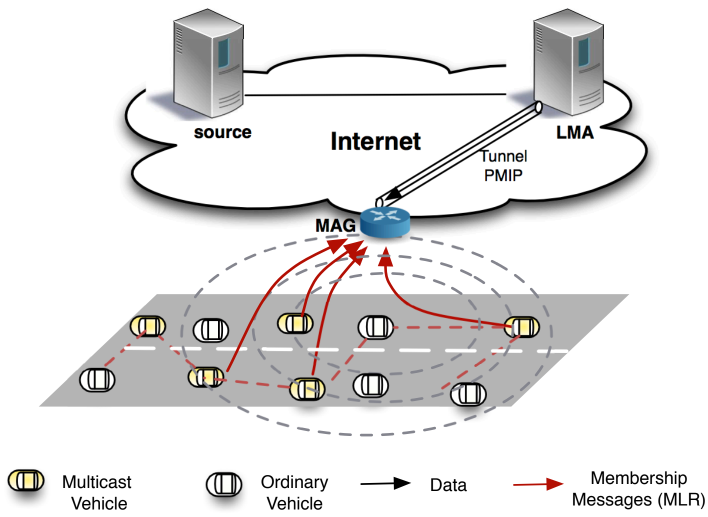

Figure 2 – PMIPv6 operations

The RSU acts as MAG and broadcasts MLQs in the VANETs. Unlike usual one-hop transmission of MLQ, in our scheme it is unicasted until it reaches the destination area. When the MLQ reaches the destination area, it is flooded in the area until it reaches at least one multicast member subscribed to the group. The multicast member that first receives the MLQ sends a MLR. Note that as specified by the protocol, if multiple members receive the MLQ, only one member respond with MLR. To do so, each vehicle sets up a random timer and the one with the shortest timer responds with a MLR. Upon reception of the MLR, the other members restrain their MLR transmission. If a node that received an MLQ is not a multicast member of the group, it simply forwards the message. The informal description of the algorithm can be found below.

3. Melody: A Reliable Geocast routing in Urban VANET

In the previous section, we proposed an extended multicast mobility management scheme that enables a MN to join a multicast group in the Internet, and thereby making it possible to create VANET multicast groups in order to disseminate multicast data to nodes using vehicular networking solutions.
Delivery of a multicast packet from the Internet to the RSU can be achieved following an Internet multicast routing protocol (e.g., Protocol Independent Multicast, PIM).
The interest of this section is to describe the multicast packets delivery approach in VANET, from the RSU to the geographic destination area, where multicast members are located. As mentioned in the previous section, geocast techniques based on flooding may create overhead on the link and result in packet collision. Moreover, opportunistic routing does not avoid packet loss and require coordination between candidate nodes to forward the packet. In this paper, we propose Melody, a variant of the opportunistic routing disseminates the multicast messages sent from the RSU to the destination area using unicast or multicast overlay paths.

```
Receive MLQ;
if  Node is MulticastMemberInDestArea or HasMulticastNeighborsInDestArea then
        Set Timer to respond with MLR;
        while TimerNotExpired do
                if MLR heard on the link then
                        return;
                end
        end
        Send MLR;
else
        Forward MLQ;
end
```

Algorithm 1 - Extended PMIPv6 for Geocast transmission

Melody operates in three phases: a neighbor discovery, relay phase, and dissemination phase. In what follows, we explain the procedures of each phase.

3.1 Neighbor Discovery

In Melody, each vehicle in the network has to maintain a list of its neighbors. To do so, vehicles periodically broadcast *Hello* messages in every second. A Hello message announces the position, the velocity, the *connectivity degree* and the multicast membership status (i.e., whether the node belongs to a multicast group or not) of the node. The connectivity degree is the number of neighbors of the node at the time of sending the Hello message. By including the membership status in the Hello message, it is now not necessary for the multicast members to periodically broadcast multicast joining requests, which is forwarded in the entire network to announce the membership status. The consequence of using the single-hop Hello messages for announcement of membership, is obviously low overhead, but also the membership status of a node is known only by its is one hop neighbors. It is indeed enough for Melody, which is an opportunistic routing algorithm.

3.2 Relay Phase

It is possible that the majority of the multicast members are far from the roadside infrastructure that receives the data from the multicast server (in the Internet). The objective of the relay phase is then to quickly and reliably deliver data packets from the RSU to the geographical areas, where the multicast members reside. Unlike traditional opportunistic routing, Melody builds a hop-by-hop overlay path until the data packet reaches the geographical area(s). Each relay that receives the multicast message retransmits it by specifying the next relay node in the packet.

The neighboring node, which is closest to the center of the destination area and which has the maximum number of neighbors (highest connection degree), is selected as the next relay for the packet (See **Figure 3**). Choosing the forwarder, which has a high connection degree, provides a high chance to guarantee that the packets reach the maximum number of multicast members.

It should be noted that since Melody targets urban road, the destination area might be segments of different roads. In this case, Melody selects relay nodes for each destination road to transmit the packet towards the destination.

3.3 Dissemination Phase

Figure 3 illustrates the dissemination phase in Melody. Dissemination phase has dual goals: 1) distributing data packet to the multicast members, which reside in the destination geographical area and 2) similar to relay phase, multi-hop message delivery from a one end to the other end of the dissemination area. To achieve the goals, we propose the following two types of Melody:

- *Melody using multicast overlay*: The relay nodes send the data packets using the multicast mode. The address of the next-hop node is indicated in the packet. Nodes that received the packet check if its address is indicated as the next hop node. If yes, it selects the next realy node and transmits a copy of packet in the multicast mode. Furthermore, if the receiving node is a multicast member it provides the packet to the multicast client application.
- *Melody using unicast overlay*: The relays generate two copies of the data message: one copy is sent to the members using the multicast mode and the second copy is sent to the next hop node using the unicast mode. While the overhead is higher than the above-described multicast overlay method, using two copies of the message improves transmission reliability as it exploits the acknowledgement procedure of the medium access control (MAC) protocol for unicast frames.

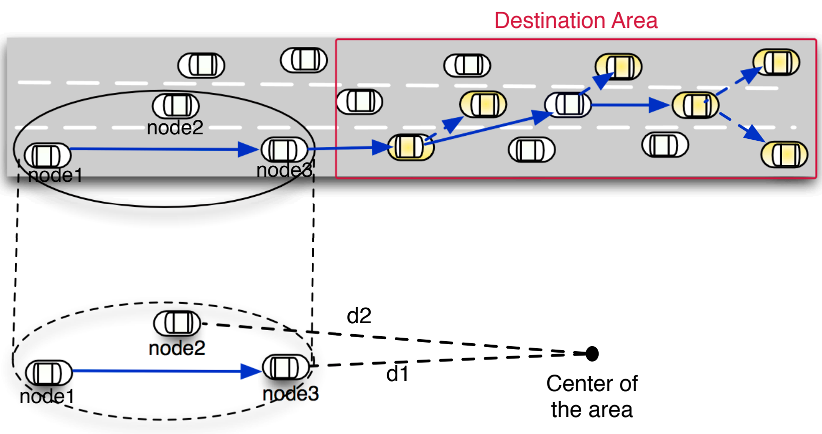

Figure 3 - Melody relay and dissemination phases

4. Performance Evaluation

Melody is implemented in the NS3 simulator [16] and its performances in terms of packet delivery ratio (PDR), end-to-end delay, and the number of packet retransmissions are compared against those of the geographical flooding approach. **Table 1** summarizes the settings of our simulations.
In the IEEE 802.11p standard [15], the communication range is around 300 meters. The Cooperative Awareness Message (CAM) specified by ETSI is used as background traffic. CAM are transmitted by each vehicle in every 100ms. Since CAM already includes position and velocity of the node, Melody uses CAM as a Hello message, by adding the necessary information such as the connectivity degree and membership status The SUMO traffic simulator [14] is used to generate realistic vehicular mobility traces. We simulated a Manhattan grid scenario as illustrated in **Figure 4**. The area length of the road is 2000x1500. The road has two lanes. The multicast members reside in the destination area. The maximum velocity of the vehicles is limited to 50km/h. The acceleration and deceleration values of the vehicles are set to 0.8 m/s^2 and 4.5 m/s^2, respectively, and the minimum inter-vehicle distance is 2.5 meters. Vehicles are generated in the grid following the Poisson process at the average rate λ (in terms of vehicles/second), which takes value on 1/15, 1/10, 1/5, or 1 that correspond to the number of nodes 160, 248, 538, or 817 respectively, as shown in **Table 1**. Ten SUMO runs of 100 seconds are carried out for each λ to obtain mobility traces for NS3.

Table 1. Simulation parameters

Simulation Parameter	Value
Simulation scenario	Urban (Manhattan Grid)
Simulation time	100 seconds
Area size	2000m*1500m
Packet size	512 bytes
Number of lanes	2 lanes
Vehicle's generation rate (car/seconds)	1/15, 1/10, 1/5, 1
Number of vehicles in the whole area	160, 248, 538, 817
Communication range	About 300 meters
Channel bandwidth	6 Mbps
Propagation model	Log distance

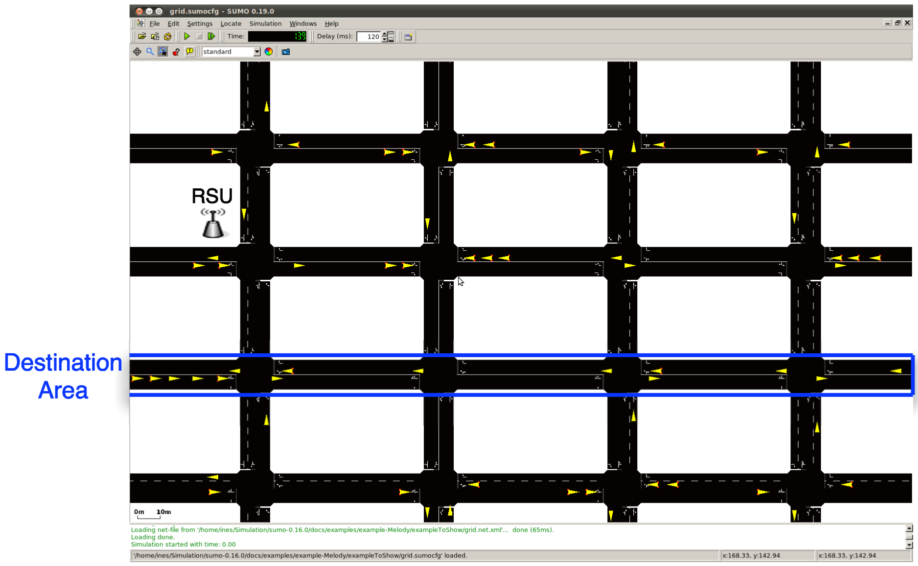

Figure 4 - Simulation scenario

Figure 5 presents the results of Melodies that use multicast and unicast overlay paths and geographic Flooding. As can be seen in the figure, both variants of Melody perform better than flooding when the number of nodes is moderately high (i.e., less than 248). Melody using unicast overlay path achieves 100% of packet delivery when the network is not highly dense, whereas Melody using a multicast relay path ensures between 95% to 80% packet deliveries. This is because using unicast path guarantees higher reliability than using multicast transmission, where no MAC-layer acknowledgement is performed. For the same densities, flooding shows low PDR: about 40%.

For high traffic density (817 nodes), however, the performances of the two variants of Melody fall considerably compared to the flooding. In the congested road scenario (817 nodes), the channel experiences high access contention by the background traffic (See Table 1), and hence the moderate number of retransmissions of data packets of Melody does not ensure the communication reliability, resulting in the reduced PDR. In contrast, flooding is not sensitive to the increase of the traffic density. The increase of the packet retransmissions even favors the PDR in certain density (value corresponding to 538 nodes in the graph). This is because in flooding each node in the network retransmits the packet that it receives in the link. Even if it creates congestion, redundant packet paths ensure at some extent packet delivery to multicast members.

Figure 6 compares the number of retransmissions of Melody and Flooding approaches. As shown in the figure, the number of retransmissions increases in Flooding when the number of nodes increases up to 538; it is small and relatively stable for the two variants of Melody. It has to be said here that Melody with unicast overlay generates more packet transmissions in compared to Melody with multicast overlay. In the dense scenario (the number of nodes is 817), the number of retransmissions of flooding as well as Melody is reduced in comparison to the case of 517 nodes. The reason behind this is as follows: the larger the number of nodes, the higher the bandwidth consumption for the background traffic and hence the available bandwidth for retransmissions of data packets is lower compared to that in lower density cases, resulting in smaller number of retransmissions. While too much retransmissions results in channel congestion and consequently low PDRs as the cases for flooding in low densities, an insufficient number of retransmission also results in low PDRs as the packets cannot reach their destinations. Indeed packet retransmissions have a direct impact on the performance of the packet delivery.

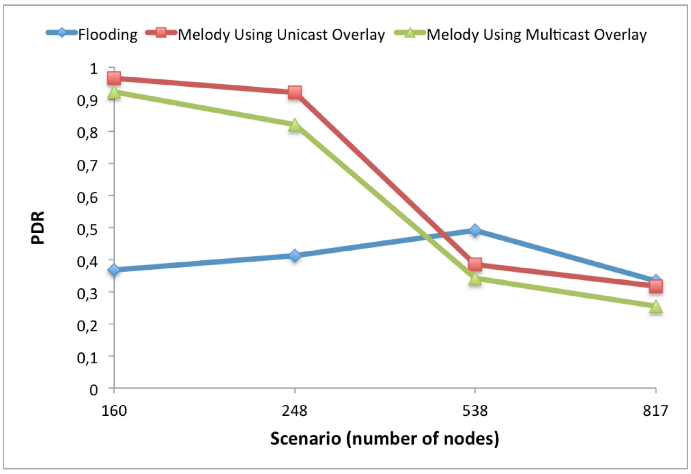

Figure 5 - Performance evaluation of the Packet Delivery Ratio

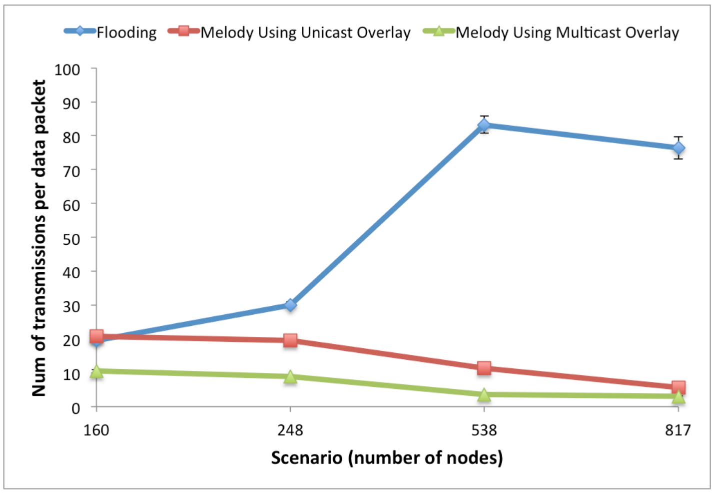

Figure 6 - Evaluation of the number of packet retransmissions

Figure 7 shows the performance of end-to-end delay. While the two variants of Melody guarantee low end-to-end delays for all multicast members in all cases of the traffic density (λ from 1/15 to 1), delays in Flooding increase considerably in high dense scenarios in the order of magnitudes (from milliseconds to seconds). In high dense scenarios, due to the excessive redundancy of the packets, which leads to high channel occupancy, the packets are buffered for a long time before being released on the channel, and this results in long end-to-end delays.

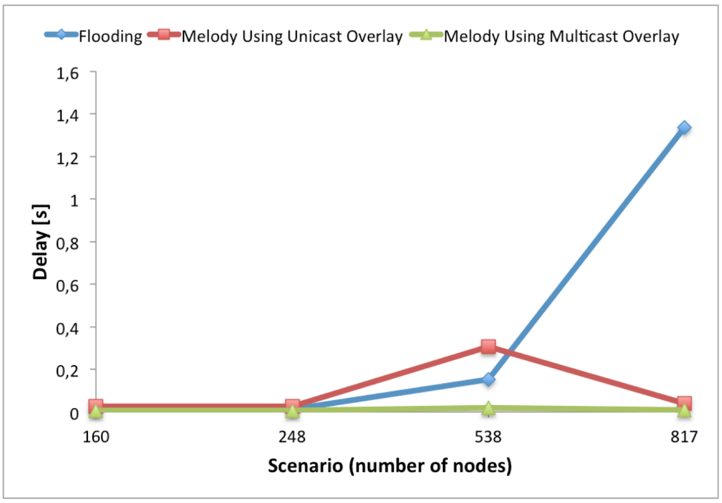

Figure 7 - Evaluation of the delay

5. Conclusion

In this paper, we propose a scheme that targets POI type of services for ITS, which require transmissions of data flows from Internet to vehicles in given geographic areas.

Our scheme extends the mobility management of multicast members of PMIPv6 by exploiting the geocast transmission in VANET. Thus, it allows reducing control overhead and expanding the POI service coverage. The proposed geocast protocol, Melody, has two dissemination approaches. The first approach exploits the reliability of the unicast transmission to relay and disseminate multicast packets in the destination area; the second approach uses only multicast transmissions and largely reduces the number of retransmissions. The performances of Melody were evaluated using the SUMO traffic simulator and NS3 network simulator. Specifically, we compared the performances of Melody and the geographic flooding in relatively dense vehicular urban scenarios. Simulation results show that Melody reduces the overhead incurred by the geographic flooding and achieves thus greater reliability in moderate dense scenario.

As a future work, we propose to improve the dissemination approach of Melody for highly urban dense scenarios.

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